ADAPTIVE METHODS

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31 July 2012

CDR Joseph Cohn
ONR: 341
875 North Randolph St
Arlington, VA 22203-1995

Re: Contract Number: N00014-12-M-0140

Enclosures: Progress Report CLIN 0001, CDRL A001

Dear CDR Cohn,

Enclosed please find a copy of Adaptive Methods Progress Report as required by the referenced contract. Distribution is made via email to all parties.

If you have any questions of a technical nature, please contact Lewis Hart at 703-968-8040 ext. 320. Contractual questions should be referred to the undersigned.

Sincerely,

Michelle Garrison

Digitally signed by Michelle Garrison
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Report Documentation Page

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ADAPTIVE METHODS

PhysicsFun4K24
Technical Progress Report

Contract N0001412M0140 - CLIN A0001
31 July, 2012

ADAPTIVE METHODS, INC.

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Contents

1 Introduction

Our approach is to provide an environment which captures the student's interest by providing an engaging story and provides educational value by mapping curriculum elements in to the fabric of that story. Both the story and the curriculum are realized in the creation of a game in a virtual world with which the student can interact; this overarching concept is illustrated in Figure 2-1. In this way we provide the student a context in an engaging virtual world that will require understanding curriculum objectives in order succeed.

1.1 Project Objectives and Requirements

The PhysicsFun4k24, or simply PhysicsFun, project has defined the following objectives:

- Formulate a gaming environment for learning a basic set of physics principles where students are fully "immersed" in lessons, enabled to discovery principles and allowed to identify limits and extension of principles through experimentation;
- Create a prototype of that environment for students to experientially explore and understand a basic set of physics principles, where students interact with the virtual world in a multi-sensory manner, and
- Provide assessments embedded into the gaming environment that examines students' attitudes, confidence, and knowledge of physics and the effectiveness of the immersive gaming environment.

Beyond the satisfaction of these objectives, there are also certain requirements that must be met in order for the concepts developed to be successfully deployed and used in early elementary STEM education:

- Present an affordable system that employs state-of-the-art 3D input devices and immersive gaming technology and leverages recent advances in computing systems, visual displays, and computer-generated imagery software.
- Create software environment designed to operate on a range of hardware configurations including laptop, PC or tabletop workstations and positioned to evolve with changing technology.
- Coordinate the PhysicsFun curriculum with teacher, school system, state and national content and standards, and allow that curriculum to be easily updated and expanded.

1.2 Deliverables

This phase of the PhysicsFun project only lays the ground work for meeting these objectives and provides foundational elements to research and build complete systems in future work. Adaptive Methods will deliver the following products as the results of these efforts:

- Research results that document the **Immersive STEM Methodology**[1] a systematic way to map curriculum to immersive game elements and to controls game progress as students learn the curriculum.
- A **seedling game**[2]**,** including the software and supporting hardware suite with multiple inputs concepts and visualization capabilities, which can be deployed and played as a proof-of-principle.

2 Immersive STEM Methodology

Science and technology motivation and education is the primary goal of PhysicsFun. This part of the research focuses on the methods and techniques for effectively mapping a STEM curriculum into an immersive environment to accomplish this end.

This methodology is architected around three principle concepts, show in Figure 2-1:

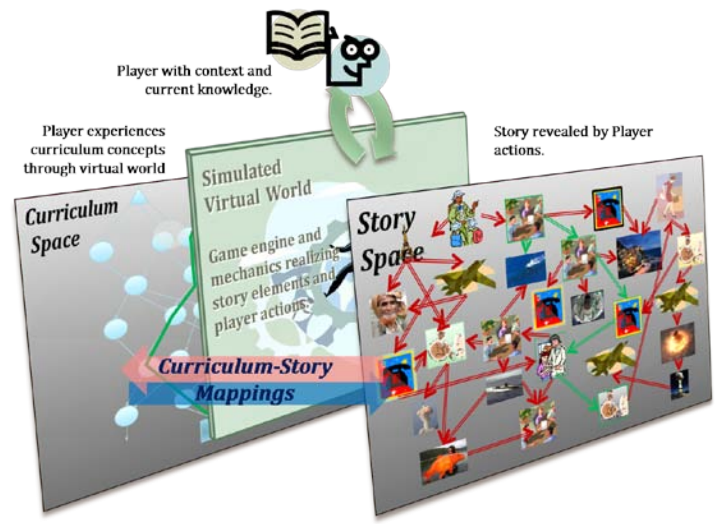

Figure 2-1 - Adaptive Methods' Immersive STEM concept, the student must apply current knowledge of a defined curriculum to succeed in the virtual world; knowledge that the student lacks can be gained while participating in the associated story presented by the virtual world.

- **Curriculum Space -** The curriculum space which provides grounding for the information being learned. It identifies the individual objectives, prerequisites, optimal and alternate pathways for learning.
- **Story Space -** The story space provides situation and context through which curriculum is experienced and explored. It is defined by a series of events, locations, characters in a narrative context.
- **Virtual World -** The story is realized using a gaming engine with appropriate mechanics, simulating the virtual world as the student interacts with it. Specific information relating to the curriculum is presented to the student or available for the student to investigate.

[1] CLIN A0002
[2] CLIN A0003, CLIN A0004, and CLIN A0005

The students experience and interact as their avatars move through the environment, seeing, hearing, finding information base on where they are and what they do.

The process starts with a concrete curriculum plan, a standard of learning or a classroom lesson plan. Typically, the plan has a hierarchical outline, collecting related topics and concepts into logical groupings. The hierarchy of topics becomes definitions for a hierarchy of modules, sub-modules and lessons.

The modules and lessons are defined by:

- Prerequisites –conditions that must be meet before this module maybe started,
- Entry assessment – a pre-assessment of the student's understanding of the modules content,
- Content – the facts, concepts, skills and ideas contained in this module, and
- Exit assessment – a post-assessment of the students understanding of the modules content.

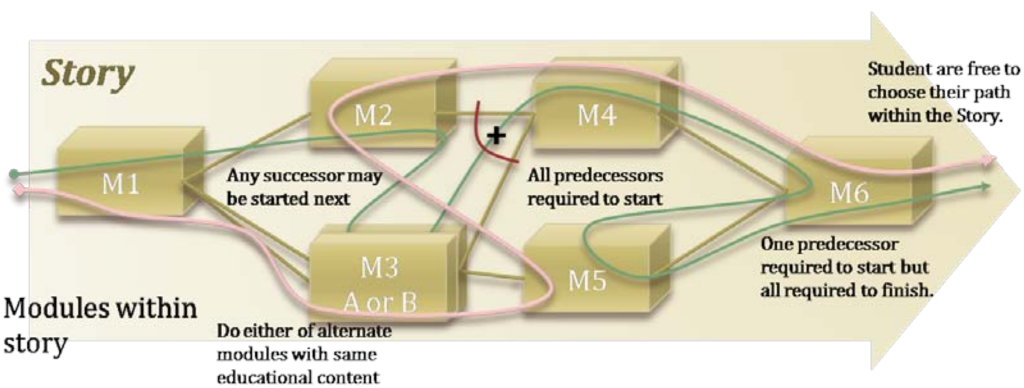

Figure 2-2 – The concept of mapping curriculum to game elements and story.

The modules are organized into the curriculum graph based upon the prerequisites of each module. Figures 2-2 shows a notional curriculum with six modules. Various types of prerequisites within the curriculum graph are possible. For example, module M4 has an "and" constraint requiring modules M2 and M3 both be completed before starting M4; M6 has an "or" constraint needing either M4 or M5 to begin. Sub-modules, such as M3 A and B, are alternate presentations of the same content. The path that the student takes through the curriculum graph is flexible, as illustrated by the pink and green paths through the modules in Figure 2-2.

The path that a student takes through the curriculum graph is flexible. Lessons are similar to modules and represent the lowest level of detail in the curriculum. Notional Lessons are shown in Figure 2-3, in a graph from completely analogous to one for modules. In this case, the entry and exit assessments are shown for the containing module.

The curriculum graph, with its modules and lessons, is the framework around which the story is woven and the inspiration for game elements. Each lesson, and some lower level modules, will be mapped to elements in the story and one or more levels in the game.

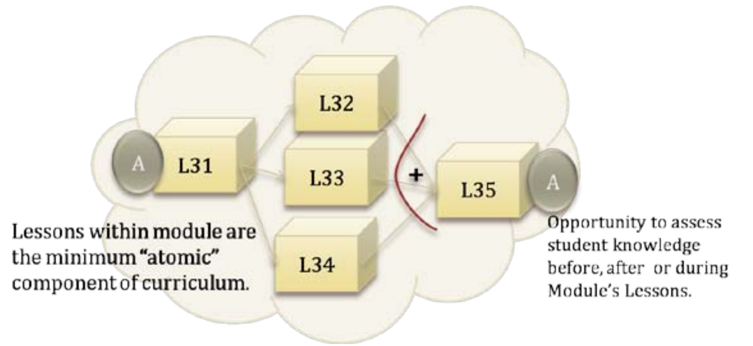

Figure 2-3 – The concept of mapping curriculum to game elements and story.

3 The Prototype Game

This section describes the concept and high level design, of the prototype's game "Jump'n Tadpoles".

3.1 Story Space– Navy Leap Frogs

Jump'n Tadpoles presents the opportunity for students to learn what it takes to be a member of the U.S. Parachute Team "Navy Leap Frogs"[3], and gain an understanding of physics along the way. During the game students will experience the effects of gravity and aerodynamic drag on a series of virtual skydiving training missions. They will learn what terminal velocity means, how to maximize their velocity and control maneuvers by understanding the relationships between air speed and their own body positions.

3.2 Curriculum Space - Force and Motion

We have developed a single physics curriculum module based on content collected from The State of Virginia Science Standards of Learning.

3.2.1 First Grade, parts 1.2 a, c, and d

Force, Motion, and Energy

1.2 The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include

a) objects may have straight, circular, and back-and-forth motions;
b) objects may vibrate and produce sound;
c) pushes or pulls can change the movement of an object; and
d) the motion of objects may be observed in toys and in playground activities.

[3] http://www.leapfrogs.navy.mil/

3.2.2 Fourth Grade, Parts 4.2 a, b and c

Force, Motion, and Energy

4.2 The student will investigate and understand characteristics and interaction of moving objects. Key concepts include

a) motion is described by an object's direction and speed;
b) forces cause changes in motion;
c) friction is a force that opposes motion; and
d) moving objects have kinetic energy.

The module will introduce students to Newton's first and second laws of motion.

- First Law – Motion only changes if forces pushing and pulling are out of balance.
- Second Law – A motions rate of change is based on the size of the push or pull.

Forces are introduced using gravity, things fall toward the earth, and drag, things moving through the air produce friction which resists motion. Velocity and acceleration are introduced as components of motion. Velocity is the basis for motion, when something has a velocity it is moving in a certain direction with a certain speed. Acceleration is the change in velocity over time. Velocities either increase (go faster) or decrease (slow down) or change direction (same speed).

A summary of physics concepts and values used during game play, underlying what is visually presented to the students, is summarized in the table below.

Parameter	Value	Notes
Time	Time during jump, in seconds	Time reset to 0.0 when a jump begins.
Altitude	Varies during jump	Altitude reset to constant (~1000m) when jump begins; integration of Velocity over Time.
Velocity	Varies during jump	Integration of Acceleration over Time
Acceleration	Varies during jump	Force divided by Mass
Mass	30kg	The "weight" of the avatar. (66 lbs), held as a constant.
Weight	294 kg-m/s^2	The force of Gravity acting on Mass
Force	Drag minus Weight	The net forces acting on the avatar (positive is up)
Gravity	9.8 m/s^2	Gravitational Constant on Earth

Drag	Coefficient * Velocity^2	The force due to moving through the air.
Coefficient	0.5*Aero*Density*Area	Values from~ 0.12 (arms out) to ~0.048 (arms in) for nominal conditions.
Aero	0.039 kg-m	Aerodynamic Constant
Density	1.23 kg/m^3	Density Earth's atmosphere (ignoring altitude).
Area	Varies from 5.0 to 2.0 m^2	Based on player position – arms in or out / up or down – determines Area which provides a contribution to Coefficient.

3.3 Game Space - Virtual World

Students' experiences from commercial off-the-shelf (COTS) games and with web content have influenced their expectations of quality in immersive interfaces. In order for these expectations to be met, high quality design and planning must be incorporated into the virtual environment. This is accomplished in the production and review of storyboards, concept graphics and game play aspects, examples are included below.

The game is designed to maximize its immersive nature. For example, menu selection is minimized, using motion and gestures were possible; displays are a part of the environment, heads up displays rather that separate delineated ones are preferred. Maximum use is made of the visual 3D and audio capabilities.

3.4 Putting it all together – Jump'n Tadpoles

The above three elements, story, curriculum and virtual world, will be combined to produce the "Jump'n Tadpoles" game. The game will consist of one curriculum module, with four lessons, as

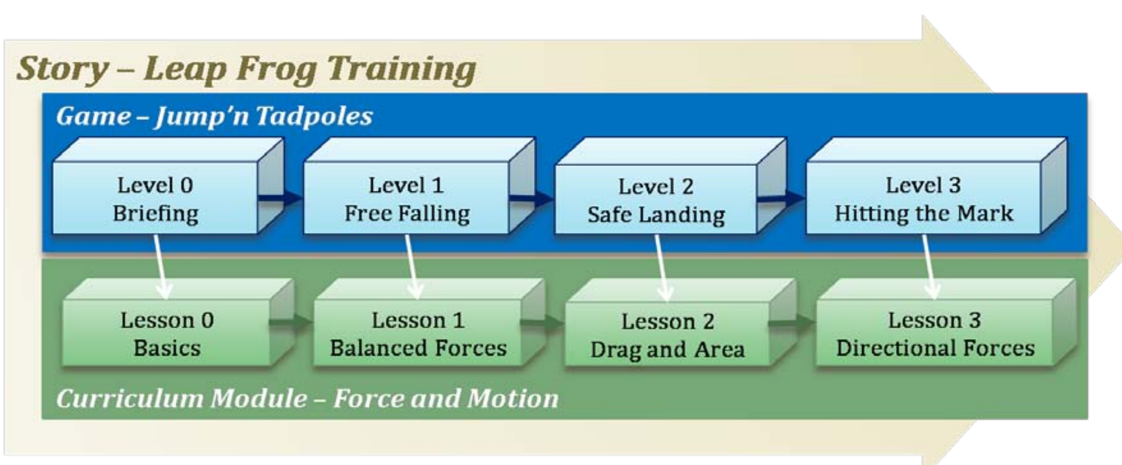

Figure 3-1 – The story provides a simple linear progression of game level mapped to a single physiscs module with four lessons.

shown in Figure 3-1, each lesson is mapped to a single level in the game. This is a very simple curriculum-to-game mapping that shows proof-of-concept. The students interact with and progress through the game using gesture and motion based APIs with both worn gloves and position tracking component as options. They are presented with a 3D presentation of the virtual world.

The game is organized internally as a series of different scenes, shown conceptually in Figure 3-

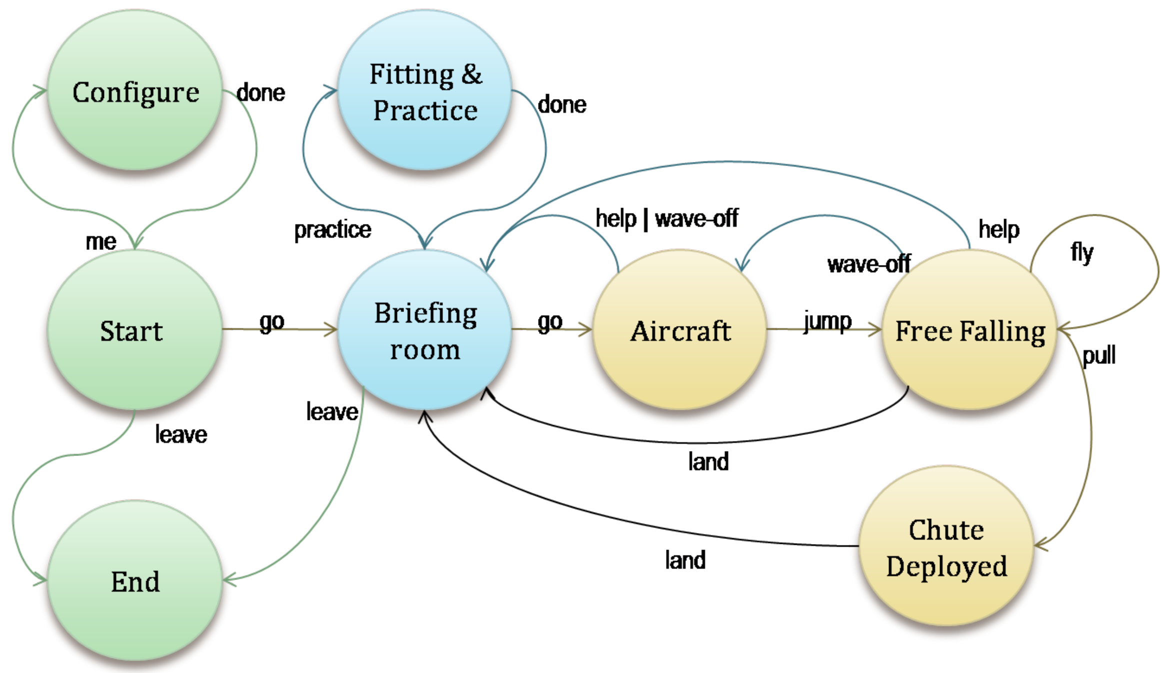

Figure 3-2 – The scenes in the game as states or modes with the possible events that cause transitions between them.

2. These scenes in the game represent one or more states or modes in the game play. The green scenes are primarily administrative, the blue are help and practice, while the yellow are actual game play. Note that the game play scenes are used slightly differently for each of levels one, two and three.

The arcs represent events, and the associated transitions between scenes and states. They may be generated either internally in game, such a "land" when the student avatar reaches the ground, or produced externally by gestures, such as "help", "jump" or "pull".

In the following sections, we provide concept artwork, Figures 3-3 to 3-6, and discuss each level of play in the game. This includes the elements from Story, Curriculum and Game that are at play in each level.

(a)

(b**)**

Figure 3-3 Concept art for the icon styles (a) and student avatar selection (b).

3.4.1 Level 0 – Briefing

This is the introductory briefing level that provides an introduction to the game, including the overall mission, objectives for each level, vocabulary and game controls (including “Practice” controls)

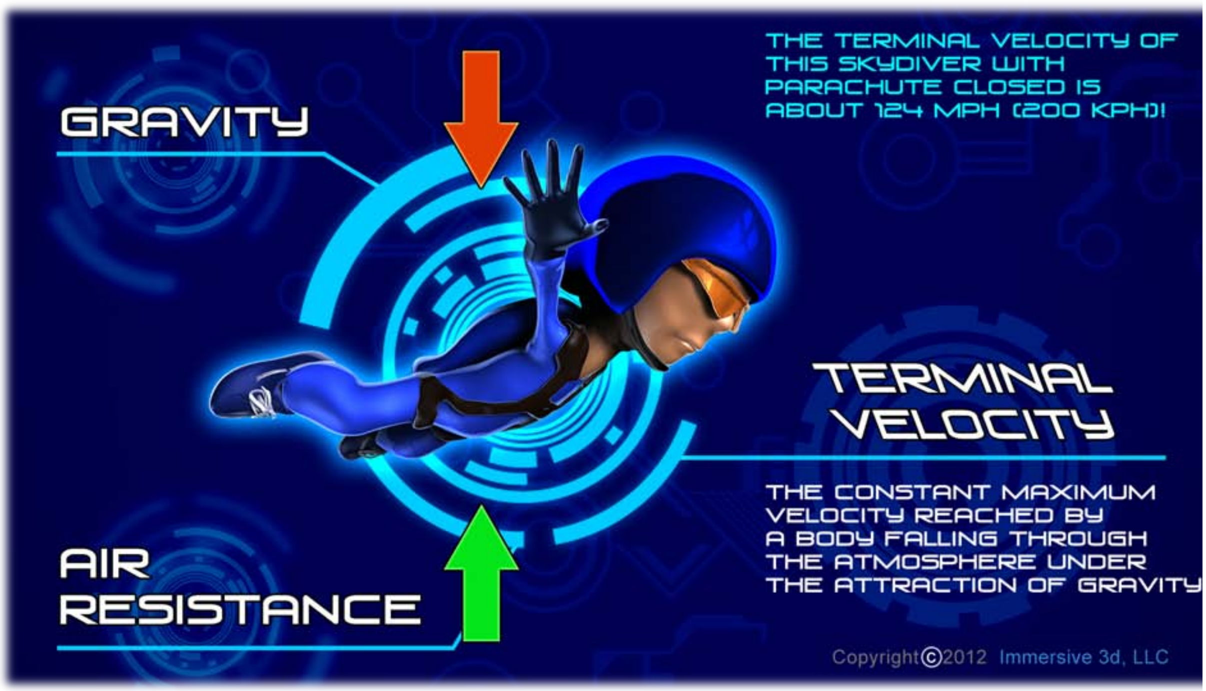

Figure 3-4- – Storyboard concept for the Briefing Room scene illustrating the explaination of Terminal Velocity as an example.

Story Elements

You are a US Navy sailor, competing to be a Navy Leap Frog. You are learning the science and skills required to effectively and safely skydive.

Curriculum Elements

- Vocabulary:
  - Area
  - Forces, Drag, Gravity
  - Acceleration, Velocity
  - Terminal Velocity
  - Atmosphere

Prerequisites

- None.

Game Elements

- Controls
    - Wave, Select, Choose
    - Jump, Spread eagle, Dive, Turn and Aim

Assessment

- Skills to use gesture interface to control game.

3.4.2 Level 1 – Free Falling

Story Elements

You need to be able to move fast. You need to determine how to reach your greatest speed during your decent. You can get faster by getting smaller.

Curriculum Elements

The ***forces of air resistance and gravity***, free fall, and terminal velocity

- Drag and gravity
- Balancing forces at terminal velocity
- Affect of position on drag

Prerequisites

- Level 0 - Successful use of controls to perform practice actions.

Game Elements

- Beginning
    - Player ready to jump from air plane at specific altitude selected via player input, default to be determined by game testing
- Controls - Input via body position
    - Jump starts
    - Spread eagle – avatar to flat position
    - Straight, arms aside – avatar to dive

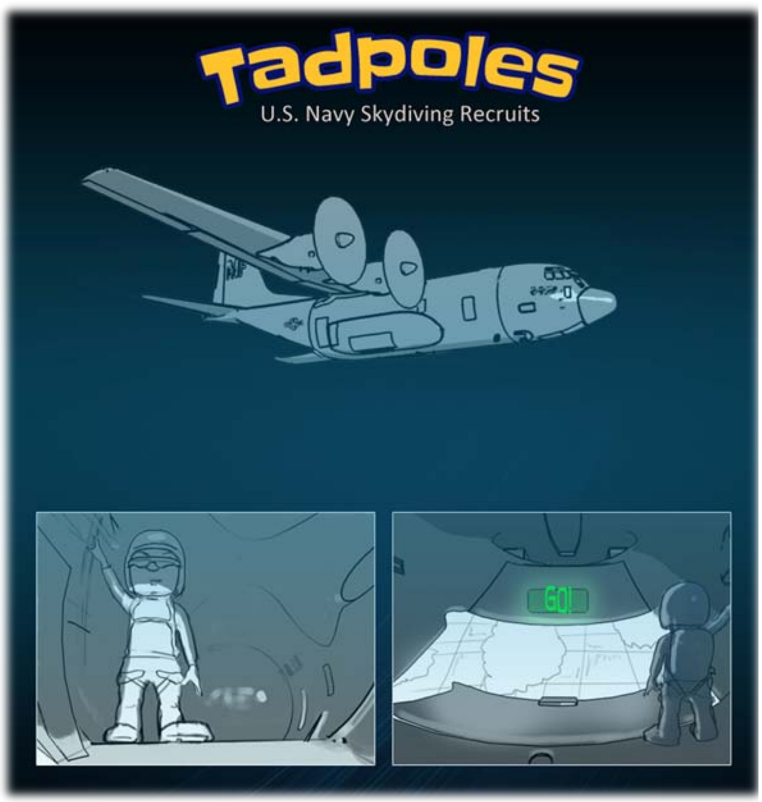

Figure 3-5 – Concpet art for Free Falling showing interior and exterior of aircraft and player viewpoint just before jumping.

- Leg(s) or arm(s) outstretched – rotational physics determines path
- Feedback
  - Arrows represent forces due to air resistance induce drag and gravity
  - When both arrows are the same size, terminal velocity achieved until the player changes position, arrows flash, and top speeds are recorded.
  - Speedometer shows current speed, arrow show up-getting faster, down-getting slower, dash – constant.

Assessment

- Understand the position to minimize the drag from wind resistance needed to maximize the player's terminal velocity.

3.4.3 Level 2 –Landing Safe

Introduces player to the forces of air resistance depending on overall shape (area) and how a parachute lowers terminal velocity.

Story Elements

You need to get down fast, but you must land safely. You can only get so slow by making yourself big, you need a parachute to go even slower.

Curriculum Elements

Opening parachute changes drag (makes a much larger) slowing you down – same weight but bigger area; body position has less or no effect with parachute deployed.

- Drag verse Area
- Shape does not affect gravity, only mass

Prerequisites

Level 1 – Reach a specified terminal velocity.

Game Elements

- Beginning
  - Player ready to jump from air plane at specific altitude selected via player input, default to be determined by game testing
- Controls - Input via body position
  - Jump starts
  - Spread eagle – avatar to flat position
  - Straight, arms aside – avatar to dive
  - Leg(s) or arm(s) outstretched – rotational physics determines path
  - Specific gesture (e.g. Pull hands over head and back to chest) to deploy chute
- Feedback
  - Time counts down to appropriate altitude
  - If pulled in time, float down with chute – thumbs up
  - If not pulled in time, Wiley E Coyote-like ending – offer to replay

Assessment

- Understand that larger areas produce larger drag forces.
    - Use parachute to slow down and land.

3.4.4 Level 3 – Hitting the Mark

Story Elements

Leap Frogs must be able to land where they want to land, so they need to know how to hit the mark. Changing your shape can change which way air is pushing you, so you can steer with you arms.

Figure 3-6 – Storyboard concept for the Hitting the Mark; shown as part of the opening splash screen. Foreshadows a goal for the students to move towards.

Curriculum Elements

- Forces have a direction.

Prerequisites

- Level 2 - Making a safe landing.

Game Elements

- Beginning
  - Player ready to jump from air plane at specific altitude selected via player input, default to be determined by game testing
- Controls
  - Same as Free Fall
- Feedback
  - Score display
  - Distance to safe chute deployment altitude
  - If pulled in time, float down with chute – thumbs up – score saved, if top score
  - If not pulled in time, Wiley E Coyote-like ending – offer to replay – no score saved

Assessment

- Understand that drag forces have direction in order to steer.
  - Collect specified number of points and land safely.

4 Measurement and Assessment

Assessment is provided at each level through scoring. In PhysicsFun the scoring system is designed around enumerated learning objectives. PhysicsFun implements an in-process game statistics engine which measures and records information on a per Player basis for assessment and review. The recorded data will be used to provide assessment of PhysicsFun's defined research objectives.

According to Interaction Designer John Ferguson, figuring out if a Human actual learned something is a difficult task. Assessing player learning in game play presents three major challenges (Ferguson, 2012):

1. How do you show that Players are learning what you claim they are learning?
2. How do you know that what you are measuring is what you think you are measuring?
3. Games that act too much like a classroom, with quizzes interrupt a player's experience.

In order for the PhysicsFun to be a successful tool that augments classroom learning it needs to incorporate learning assessment, and evaluation capabilities into Game Play.

4.1 Physics Fun

Assessment and evaluation in Jump'n Tadpoles, (and Future PhysicsFun Game installments), is based upon proven Game Play pedagogical and psychometric measurement strategies.

The focus is to create an environment where learning is definable, quantifiable and measurable. PhysicsFun's pedagogical approach incorporates science and technology lesson plans and assessments seamlessly into the game play sequence.

By employing an integrated approach PhysicsFun is not bound to traditional classroom evaluation applications (e.g. the administration of series simple multiple-choice questions at the conclusion of an interactive Game Play scenario).

In PhysicsFun, dynamic Game Play measurements are employed to support Game Play evaluation/assessment, to control player advancement, and to provide post Game Play statistical analysis.

4.2 Assessment Techniques

Three types of assessment are commonly used in educational games:

- Completion Assessment - Did the player complete the lesson or pass the test?
- In-Process Assessment - How did the player choose his or her actions? Did he or she change their mind? If so, at what point?
- Teacher Evaluation - Based on observations of the player, does the teacher think the player now knows/understands the material?

According to Kevin Corti, Managing Director of PixeLearning, “Completion assessment is the simplest form of assessment: Did the Player complete the game? This is equivalent to asking, "Did the student get the right answer?" Since games are simulations, this simple criterion could be the first indicator that the Player sufficiently understands the subject taught. This is *not* the same as asking, "Did the student attend every class?" Because games require interaction by the Player with the material, completing the game signifies more learning progress and comprehension than passively attending a class in a typical classroom setting.” (Corti, 2012)

It is important to understand that completion assessment cannot distinguish whether a Player understands the game lesson, or has just learned how to beat the game.

In-process assessment is analogous to teacher observations of the student as the student performs the task or takes the test. In PhysicsFun our in-process assessment measures:

- Time required to complete a Game level;
- Mistakes;
- Self-corrections actions.

Teacher evaluation is a combination of both completion assessment and in-process assessment. Teacher evaluation can also include observation of Players in action. Multiplayer video games often include "observer modes" that could be used for this, both by the teacher and other students.[4]

4.3 Post Games Quiz

In PhysicsFun Assessment starts pre-game, runs all the way through the game. Applying a simple post-game multiple-choice questionnaire at the conclusion of a Players experience is not always the best measurement technique. Players come to understand the connection between their in-game actions and the outcomes.

[4] Jim Brazell, consulting analyst at the Digital Media Collaboratory (DMC) in the IC² Institute at the University of Texas at Austin, www.ic2.u**texas**.edu.

The application of a simple assessment engine supports player assessment and post-play evaluation. If a player performs X what was the basis for the action, why not Y? The assessment engine in PhysicsFun records individual player action. Player actions can be evaluated to determine how well the player understood the targeted learning objectives.

4.4 Learning Assessment

Science and technology education is the primary goal of PhysicsFun. All Leap Frogs and Future PhysicsFun Game installments are architected around set of enumerated learning objectives derived from age-appropriate science and technology curriculum.

Each installment in PhysicsFun employs a multi-level game format. In level 0, the tutorial:

- The player is introduced to a enumerate set learning objects;
- The player is presented with basics instructions of how to control and interact with the Game;
- The player is provided and explanation of how the series of interface actions map to the enumerated learning objectives;
- The player is provided with a limited Game Play scenario that demonstrates game controls; if sufficient mastery of the controls is performed the Player can proceed to the next level of Play.

In Level 0 a mission brief introduces specific Game Play criteria and reinforces the learning objectives.

PhysicsFun employs pass/fail mechanisms to enforce Prerequisites through subsequent levels. Assessment is provided at each level through scoring. The scoring system is design around the enumerated learning objectives.

Game play in PhysicsFun places less emphasis on rote memorization of facts than applying traditional learning methods. Open-ended Game scenarios are presented to players that wide range of possible solutions all of which could be correct. Measurements are included for both in game evaluation / control of Prerequisites and after play statistical analysis. The linkages of content to game play known, but cannot be directly observed. That is how we know the student understands the concepts in the curriculum based on actions in the game. To support inferential assessment the mapping of content will be mapped to in game action allowing only students with knowledge of concept X to succeed at game element Z. Ideally success with game element Z implies understanding of X.

4.5 Logging Measures

In order to provide data for longer term, broader analysis of student comprehension and engagement it is necessary to provide a systematic recording of students' behavior in game into persistent log. Each measure that is recorded must be well designed and meet a minimum set of requirements to support rigor in subsequent analysis; each measure shall be:

- Atomic – uninterrupted events and actions in the game.
- Clearly defined – unambiguous & usable – records a significant event
- Have sufficient Context –records all relevant contextual data
- Efficient – suitable for in game use as well as post play analysis

In addition to these specific requirements, the measures in aggregate must answer the questions being asked by the research. Our objectives are twofold, to motivate students interest in science and technology and to provide skill necessary to succeed. Target behaviors that reflect skills needed to be successful may include: problem solving, situation awareness, decision making, conceptual learning and procedural learning.

PhysicsFun implements an in-process game statistics engine. The engine measures and records this information on a per Player basis for assessment review. The measures that will be recorded in PhysicsFun will at a minimum record:

- Who the student is – id, school, etc;
- What the student did – direct actions, not inference by game results;
- When events occurred in game and real time -- level completion, mistakes made, self-corrections, etc;
- Where (contextually) in the game the event occurred – level, scenario, specifics of play, etc.

The measure logs will be used to calculate aggregate statistics, such as average time required completing a game level, number of mistakes made, and number of self-corrections made; to provide an assessment of satisfaction of research objectives.

5 Interface Concepts

The principal interface for PhysicsFun will be Gesture based. There has been a significant amount of prior research into the types and effectiveness of gesture based interfaces(User-Defined Gestures for Surface Computing, April 2009) (Karam, November 2006) (A taxonomy of Gestures in Human Computer Interaction, 2005). We have developed a basic taxonomy, shown in Figure 5-1. This taxonomy will be used to guide the development of the PhysicsFun interface and to identifying potential alternative approaches.

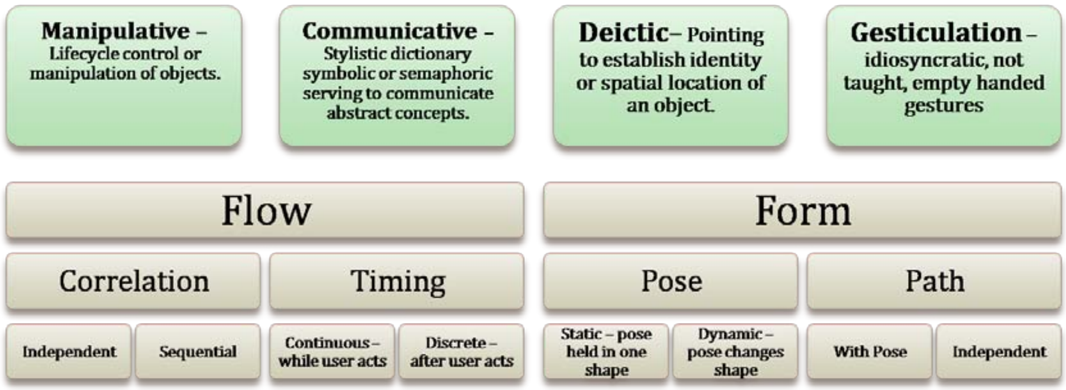

Figure 5-1 – Our simple taxonomy of gesture types and characteristics provides aguide to further investigation of interface approaches.

We have performed a preliminary analysis of the types and nature of controls that will be required for the seedling game, mapping each game event into the gesture taxonomy. The result of this analysis is presented in the table below which maps the events from the game map, Figure 3-2, to the gesture type and description of Figure 5-1.

Game Event	*Gesture*			
	Type	*Flow*	*Form*	*Comment*
done	Deictic/ Communicative	Independent / Discrete	Static	Complete and leave a special mode, e.g. stop configuring avatar.
Fly	Manipulative / Gesticulation	Independent / Continuous	Dynamic	The arm and leg motions used to direct the avatars flight.
go	Deictic/ Communicative	Independent / Discrete	Static	Begin play by entering the appropriate game level.
help	Deictic/ Communicative	Independent / Discrete	Static	Go to Briefing Room for help.
jump	Manipulative / Gesticulation	Independent / Discrete	Dynamic	Jump from Aircraft to begin Free Falling.
land	N/A	N/A	N/A	Automatic in game event.
leave	Deictic/ Communicative	Independent / Discrete	Static	Leave the game.
me	Deictic/ Communicative	Independent / Discrete	Static	Begin avatar configuration.

practice	Deictic/ Communicative	Independent / Discrete	Static	Go to Fitting and Practice area.
pull	Manipulative / Gesticulation	Independent / Discrete	Dynamic	Open the parachute.
wave-off	Communicative	Independent / Discrete	Dynamic	Abort the jump and return to Aircraft or Briefing Room

Two basic types of gesture events have been identified. Game Control gestures which are primarily communicative, discrete and static (shaded blue), and Game Play gestures which are primarily manipulative, continuous and dynamic (shaded orange).

Game Control gestures are used to navigate and make selections in game. These have traditionally been performed using menu selections or keyboard entry. We are exploring several options for these types of gestures:

- Selection of icons by pointing to them and hovering or using a selection gesture, such as in Figure 5-2(a); and
- A separate static gesture, such as a simplification of American Standard Sign language, for example those in Figure 5-2(b).

The Game Play gestures represent a more complex and diverse set. Three gestures, *jump, fly* and *pull*, are those which the student uses to manipulate their avatar in game, such as jumping out of the aircraft to begin. These will be based on gesticulation, using the natural motion analogous to the desired avatar action; that is the student would jump up to gesture *jump* or reach over head and then pull down to gesture *pull*. In these two cases the gestures are recognized as discrete events. The *fly* gesture, while perhaps not truly a gesticulation to the students, would be using typical sky diving positions to control speed and direction. This gesture is continuous, monitoring the student's body position during game play. The fourth Game Play gesture, *wave-off*, is used to abort the game in mid-play and is a Communicative rather than a Manipulative gesture. An important focus of research is the detection of these discrete events, while monitoring the continuous gestures (E.G. *fly*) and ignoring random gesticulation.

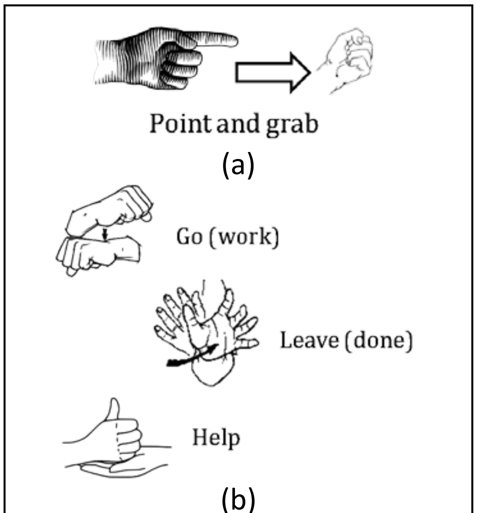

Figure 5-2 – Gestures being explored for Game Control; menu selection (a) or standalone signs(b).

5.1 Calibration

The calibration of real-world gestures with virtual world is required because the students range significantly in physical size. As part of each student's log-in a set of calibration data will be collected in order to synchronize real and virtual world location references. This will be done once for each new student and optionally repeated if the need arises. Calibration will be accomplished by directing the student player to "touch" a series of object in the virtual world. The actual, real-world positions corresponding to the virtual world locations touched will be recorded. This will establish a baseline calibration.

During game play, a "sticky" object model may be used to provide continuous tracking of calibration during game play. This process assumes that students pointing close to an object and gesturing to "select" it implies a real world position for the virtual object allowing fine tuning of calibration.

5.2 Voice Command

Some input devices, most notably the MS Kinect, has voice command capability. The potential for combinations of deictic or manipulative gestures with simple voices commands could potentially provide a more intuitive interaction. For example, pointing a menu item and saying "That one", rather than gesture alone. Best practices (Microsoft Coporation, 2012) indicate that voice commands are most suitable for quiet, controlled environments. Base on this recommendation, we believe that voice controls are not well suited to an early elementary grade classroom; voice command will not be investigated further in this phase of the research.

5.3 Keyboard and Mouse Command

While the focus of the PhysicsFun project is on immersive environments, we believe that a greater range of students may be engaged by supporting traditional keyboard, mouse or gamepad commands as well. Where possible, traditional equivalent commands will be available for game control.

6 System Architecture

PhysicsFun combines special purpose input hardware and computer gaming software to provide an overall system archetecture shown in Figure 6-1.

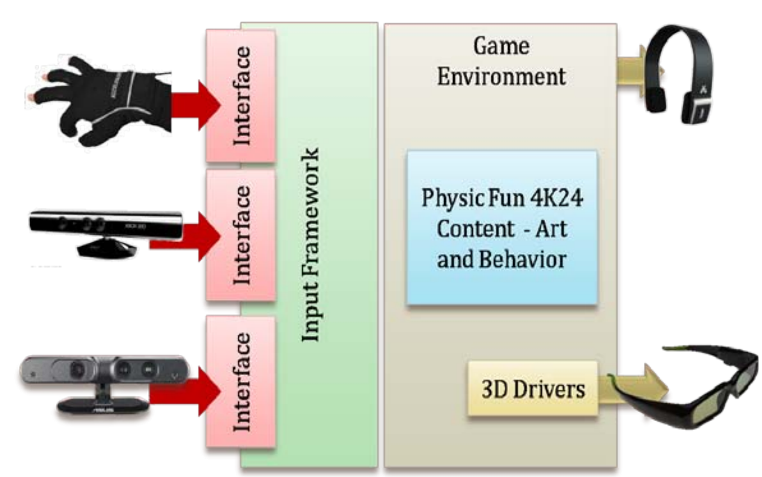

Figure 6-1 – High level system architecture for PhysicsFun -

6.1 Hardware Architecture

The core hardware used for PhysicsFun is a commercial off the shelf Dell T1600 Fixed Workstation equipped with a quad-core Xeon processor running Windows 7 Ultimate. It has been augmented to support 3D graphics with a ASUS ENGTX560 graphics card, ASUS 27” 120Hz LCD display and Nvidia active 3D glasses.

Three gesture-based input devises are being investigated:

- AcceleGloves – A pair of gloves with six embedded sensors per hand to provide hand and finger acceleration measurements,
- Microsoft Kinect - A camera and audio based system which provides body skeleton tracking in three dimensions and directional sound/voice recognition,
- ASUS Xtion PRO – A camera based system which provides body skeleton tracking.

Each device has associated drivers and SDKs which provide the basic hardware interface.

6.2 Software Architecture

The software architecture has two principal components. The hardware devices are mediated through an Input Framework which isolates the hardware details from game implementation. The second component is the Gaming Environment in which the actual game art and behaviors are developed and deployed.

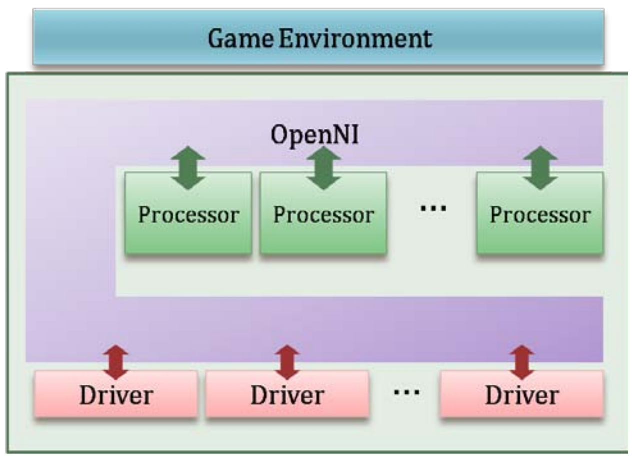

Figure 6-2 – A generic architecture based on OpenNI allows the inclusion and evolution of hardware and software components.

6.2.1 Input Framework

The input device hardware will be connected to the game engine through an Input Framework. The main purpose of this framework is to provide, as far as possible, a device agnostic input stream; it be based on the OpenNI [5] architecture as shown in Figure 6-2. OpenNI is an open source project sponsored by a number of private companies [6] interested in open gesture-based interfaces.

OpenNI is an open source project which seeks to provide exactly the hardware agnostic environment which is needed for PhysicsFun.

The functionality need by the PhysicsFun application will be provided in middleware processors using the OpenNI APIs and data objects. These processors can be organized at runtime into processing strings to dynamically create different process capabilities and architectures.

[5] http://www.openni.org/
[6] For example PrimeSense http://www.primesense.com/, and ASUS http://usa.asus.com/

6.2.2 Game Environment

The Game Environment is the Unity 3D Integrated Development Environment[7]. It is an integrated development environment for the development of 3D video games or other real-time 3D interactive applications. The Unity development environment will run on both Microsoft Windows and Mac OS X platforms; the deployment environments include Windows, Mac, Xbox 360, PlayStation 3, Wii, iPad, iPhone, Android, and Linux. PhysicsFun development will be using Unity to develop and deploy a standalone application for the Windows environment. Unity integrates the Input Framework using Microsoft .NET dll libraries provided by the framework.

7 Works Cited

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[7] http://unity3d.com/